APPLICATION FOR PATENT

Title: Expandable Packer with Anchoring Feature

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PRIORITY INFORMATION

[0001] This application is a continuation-in-part of prior U.S. application number 10/117,521, filed on April 5, 2002, which claims the benefit of U.S. Provisional Application No. 60/344,314 filed on December 20, 2001.

FIELD OF THE INVENTION

[0002] The field of this invention relates to packers and more particularly to packers that can be set by expansion and more particularly incorporating an anchoring feature to engage the surrounding tubular upon physical expansion of the packer.

BACKGROUND OF THE INVENTION

[0003] Traditional packers comprised of a sealing element having anti-extrusion rings on both upper and lower ends and a series of slips above or/and below the sealing element. Typically a setting tool would be run with the packer to set it. The setting could be accomplished hydraulically due to relative movement created by the setting tool when subjected to applied pressure. This relative movement would cause the slips to ride up cones and extend into the surrounding tubular. At the same time, the sealing element would be compressed into sealing contact with the surrounding tubular. The set could be held by a body lock ring, which would prevent reversal of the relative movement, which caused the packer to set in the first instance.

[0004] As an alternative to pressure through the tubing to the setting tool to cause the packer to set, another alternative was to run the packer in on wire line with a known electrically operated setting tool such as an E-4 made by Baker Oil Tools. In this application, a signal fires the E-4 causing the requisite relative movement for setting the packer. Some of these designs were retrievable. A retrieving tool could be run into the set

packer and release the grip of the lock ring so as to allow a stretching out of the slips back down their respective cone and for the sealing element to expand longitudinally while contracting radially so that the packer could be removed from the well.

[0005] In the past, sealing has been suggested between an inner and an outer tubular with a seal material in between. That technique, illustrated in U.S. Patent 6,098,717, required the outer tubular or casing to be expanded elastically and the inner tubular to be expanded plastically. The sealing force arose from the elastic recovery of the casing being greater than the elastic recovery of the inner tubular, thus putting a net compressive force on the inner tubular and the seal. Other expansion techniques, described in U.S. Patents 5,348,095; 5,366,012; and 5,667,011 simply related to expansion of slotted tubulars, serving as a liner in open hole, as a completion technique. U.S. Patent 4,069,573 illustrates the use of expansion to form a tubular casing patch.

[0006] The present invention relates to construction features and methods of employing packers that can be expanded into sealing position. The surrounding tubular does not need to be expanded to set the packer of the present invention. Rather, an anchor such as slips is used to support the expanded sealing element and hold it in a set position. Preferably, existing setting tools, with minor modifications can be used to expand the packer of the present invention. Similarly releasing tools can be employed to remove the packer from its set position. The running string can be exposed to lower pressures than the packer through the use of pressure intensifiers. The expansion force can be pinpointed to the area of the packer, thus avoiding subjecting the formation or the running string to undue pressures during setting of the packer. Alternatively, the inner tubular may simply be an anchor for another tool or a liner string. The anchoring can be ridges on the exterior of the inner tubing directly or on a ring mounted over the inner tubular being expanded. The ring can be slotted to reduce the required expansion force. The slips are retained to the mandrel by undulating mating surfaces. The grip area is enlarged to reduce stress on the tubular. Features are included to help hold the set on shifting load conditions and to augment the applied force on the sealing element. A variety of potential applications are illustrated.

[0007] The setting tool can be delivered through tubing on slick line or wire line or run into the well on rigid or coiled tubing or wire line, among other techniques. The release tool can be likewise delivered and when actuated, stretches the packer or anchor out so that it can be removed from the wellbore. Conventional packers, that have their set held by lock rings, can be released with the present invention, by literally pushing the body apart as opposed to cutting it downhole as illustrated in U.S. Patent 5, 720,343.

[0008] These and other advantages of the present invention will be more readily understood from a review of the description of the preferred embodiment, which appears below.

SUMMARY OF THE INVENTION

[0009] An expandable packer or anchor is disclosed. It features a gripping device integral to or mounted in a sleeve over the mandrel and mating undulating surfaces to help maintain grip under changing load conditions. Upon expansion, pressure on a sealing element is enhanced by nodes to increase internal pressure as it engages an outer tubular. Adjacent retaining rings limit extrusion and enhance grip. A gripping device, such as wickers on slips, preferably digs into the outer tubular. The expansion is preferably by pressure and can incorporate pressure intensifiers delivered by slick line or wire line. Release is accomplished by a release tool, which is delivered on slick line or wire line. It stretches the anchor or packer longitudinally, getting it to retract radially, for release. The release tool can be combined with packers or anchors that have a thin walled feature in the mandrel, to release by pulling the mandrel apart.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1 is a section through the packer of the present invention in the run in position;

[0011] Figure 2 is the view of Fig. 1 with the packer in the set position;

[0012] Figure 3 is an outside view of the packer showing the slips on a ring with recesses;

[0013] Figures 4a-4d show the packer schematically prior to expansion using a pressure intensifier;

[0014] Figures 5a-5d show the packer of Figs. 4a-4d in the set position with the through tubing pressure intensifier removed;

[0015] Figures 6a-6b show schematically how force is to be applied to release the packer;

[0016] Figures 7a-7b show the released position of the packer after applying the forces shown in Figs. 6a-6b;

[0017] Figures 8a-8b show one version of a release tool for the packer where the release tool is tubing delivered to latch to the top of the packer;

[0018] Figures 9a-9b show a through tubing release tool, which can be delivered on wire line or slick line;

[0019] Figures 10a-10d show a packer with a mandrel having a thin wall segment with a release tool inserted through tubing and the packer in the set position;

[0020] Figures 11a-11d show the packer of Figs. 10a-10d in the released position.

[0021] Figures 12a-12e show the packer run in with a wire line or hydraulic setting tool in the run in position;

[0022] Figures 13a-13e show the packer of Figs. 12a-12e in the set position with the setting tool released;

[0023] Figure 14 is a section view during run in of a preferred embodiment showing the nodes under the sealing element and the undulating surface contact for the slips;

[0024] Figure 15 is the view of Figure 14 in the expanded and set position;

[0025] Figure 16 is a variation of the packer shown in the set position in Figure 15 showing a line or conductor through its body;

[0026] Figure 17 is a section view of a prior art packer in the run in position showing the relatively short slip length involved, which leads to a greater stress on the surrounding tubular;

[0027] Figure 18 is the packer in Figure 17 in the set position;

[0028] Figure 19 is a section view in the set position of the packer of the present invention showing the longer slip lengths leading to a reduced stress on the surrounding tubular;

[0029] Figure 20 shows the use of the packer of the present invention when drilling out a plug;

[0030] Figure 21 is the view of Figure 20 after the plug is drilled out;

[0031] Figure 22 is the view of Figure 21 after the bit is released;

[0032] Figure 23 is the view of Figure 22 with the packer expanded to the set position;

[0033] Figure 24 is a section view of an application of the packer of the present invention to a liner top isolation packer next to a liner hanger;

[0034] Figure 25 shows a set packer having an interior plug;

[0035] Figure 26 is the view of Figure 25 showing running in with a string with a seal, a retrieving tool and a sinker bar;

[0036] Figure 27 shows the plug being knocked out and the seals landed in the packer;

[0037] Figure 28 shows the retrieving tool releasing the packer by stretching it;

[0038] Figures 29a-b are a section view of a one-trip packer with pressure intensifier in the run in position;

[0039] Figures 30a-30b are the packer of Figures 29a-29b in the set position;

[0040] Figures 31a-31b are the packer of Figures 30a-30b shown in the ball released position;

[0041] Figure 32 shows a latching grove for a slick line plug used as an alternative to setting the packer;

[0042] Figure 33a-33e is an alternative embodiment showing an internal recess on the slips against a cylindrical expansion mandrel, in the run in position;

[0043] Figures 34a-34e are the view of Figures 33a-33e in the set position; and

[0044] Figures 35a-35f are the view Figures 34a-34e in the ball release position.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0045] Referring to Fig. 1, the packer P has a mandrel **10** with an upper thread **12** and a lower thread **14**. Upper slip ring **16** attaches at thread **12** and has extending slips **18**. As shown in Fig. **3**, slips **18** are fingers of preferably metal separated by slots **34**. One purpose of the slots **34** is to decrease resistance to expansion. Another is to allow the wickers **32** to be hardened. If the slips were to be continuous and have hardened wickers **32**, the brittleness would cause the slips to crack on expansion. Lower slip ring **20** attaches at thread **14** and has finger like slips **22** extending from it. Slips **18** and **22** each have wickers or some other surface sharpness **32** designed to dig in for a supporting bite into the casing C upon expansion of the mandrel **10**. A sealing element **24** having backup rings **26** and **28** is disposed between slips **18** and **22**. Those skilled in the art will appreciate that the slips **18** and **22** can be formed as an integral part of the mandrel, thus eliminating the threads **12** and **14** as well as the rings **16** and **20**. In that event, the slips **18** and **22** can be a series of finger shaped protrusions from the outer surface of the mandrel **10**. These protrusions can be integral, welded, or attached in some other way. Although a packer has been described, the sealing element **24** can be eliminated and the slips **18** and

22, regardless of how they are attached, can be used to anchor a tubing string (not shown) or a tool (not shown) attached to the mandrel **10**, when the wickers **32** dig into the surrounding casing ℂ. Conceivably, the expansion of the wickers **32** into the casing or outer tubular ℂ can accomplish not only a support function but also a sealing function. Sealing is possible without having to appreciably expand the casing ℂ or even without expanding the casing ℂ at all. The invention can be effective with a single or multiple rings of slips, regardless of their attachment mode, and with a variety of known designs for the sealing element **24**.

[0046] The clear advantage of the present invention is that cones are not required to drive the slips outwardly. This means that for a given outside diameter for run in, the packer or anchor ℙ of Fig. **1** will have a larger internal bore diameter than a design relying on cones to ramp slips out. The larger bore possible in the mandrel **10** comes with no significant reduction of the pressure rating of the packer ℙ.

[0047] The wickers **30** and **32** are preferably hardened to facilitate penetration into the casing. The sealing element **24** is preferably Nitrile but can also be made from other materials such as Teflon or PEEK. The backup rings **26** and **28** are preferably ductile steel and serve the function of keeping the sealing element **24** out of the slots **34** between the slips **18** and **22**. Rather than slots **34** to facilitate expansion of the slips **18** and **22**, the sleeve that holds the slips can be made thinner or have other openings, such as holes, to reduce its resistance to expansion. The expansion itself can be carried out with known expansion tools such as roller expanders, swages, or cones. Alternatively, an inflatable can be used to expand the mandrel **10** or a pressure technique, as illustrated in **4a-4d, 5a-5d, 12a-12e,** and **13a-13e**.

[0048] Figs. **4a-4d** illustrate a thru-tubing approach to setting where either a slick line or a wire line can be used to deliver a pressure intensifier **36** to a desired position where it will latch in the tubing **37** adjacent the packer or anchor ℙ. The packer or anchor ℙ is illustrated schematically as is the connection at the top of the intensifier **36**. Pressure applied into tubing **37** enters ports **39** and **40**. Pistons **42, 44,** and **46** are connected together for tandem movement. Pressure from ports **39** and **40** enters cavities **48** and **50**

to apply downward forces on pistons **42, 44,** and **46**. Additional pistons can be used for greater force amplification. The use of intensifier **36** allows a lower pressure to be used at the wellhead in case it has a low pressure rating and the expansion force desired at the packer or anchor P exceeds the rated wellhead pressure. Downhole movement of piston **46** forces fluid out of port **52** to expand the packer or anchor **P**. The intensifier **36** is retrieved after expansion with a known fishing tool, which engages a fishing neck in the top of the intensifier. As shown in Figs. **5a-5d,** the packer or anchor P is set against tubular or casing C and the intensifier is removed from the tubing **37**.

[0049] Another way to deliver and set the packer or anchor P is shown in Figs. **12a-12e** and **13a-13e**. In these figures the packer or anchor P is delivered on a hydraulic or wire line setting tool, as opposed to the through-tubing techniques previously described. The setting tool is schematically illustrated to cover the use of both hydraulic or wire line setting. A sleeve **54** abuts the top of the packer or anchor P (Fig. **12d**). A gripping sleeve **56** retains the packer or anchor P until the shear stud **58** fails. Circulation is possible when using the hydraulic setting tool until an object is dropped to allow pressure buildup to ultimately move piston **60** to set the packer or anchor P. Upward movement of the piston **60** breaks the shear stud **58** after delivering the required pressure for expansion through port **62** to the packer or anchor P. The hydraulic setting tool can incorporate pressure intensifiers so as to limit the surface pressure applied to get the desired expansion, in the event the wellhead has a low pressure rating. Breaking the shear stud **58** allows removal of the setting tool and a subsequent tagging the packer with production tubing. The pressure intensifier can have more or fewer pistons to get the desired pressure amplification. Hydrostatic pressure can be employed to do the expanding instead of or in conjunction with surface applied pressure. Various ways can be used to connect the tubing to the packer. The expansion tool can be released from the packer by rotation. Known setting tools can be employed such as those made by Baker Oil Tools under model numbers BH, BHH, B-2 and J with only slight adaptations.

[0050] In a wire line variation, the setting tool would be electrically actuated to set off an explosive charge to create the needed pressure for expansion of the packer or anchor P in the manner previously described with the possibility of integrating a pressure

intensifier. Once the packer or anchor P is expanded, an automatic release from the setting tool occurs so that it could be removed. Known wire line setting tools like the E-4 made by Baker Oil Tools can be used, or others. The expansion concept is the same, stroking a piston with a pressure source and, if necessary a pressure intensifier, creates the pressure for expansion of the packer or anchor P to expand it into position against the tubular or casing C and to trigger an automatic release for retrieval of the settling tool. After the setting tool is pulled out, tubing is tagged into the expanded packer or anchor.

[0051] Release of the packer or anchor P is schematically illustrated in Figs. **6a-6b**. The technique is longitudinal extension as illustrated by opposed arrows **64** and **66**. This longitudinal extension results in radial contraction, shown schematically as arrow **68**. What actually occurs is that the wickers **30** and **32** (shown in Fig.**1**), which had dug into the casing C on expansion, are pulled or sheared out of the casing. The longitudinal extension also draws back the sealing element **24** as the mandrel under it radially contracts. Figs. **7a-7b** show the released position.

[0052] One way to accomplish the release as described above is shown in Figs. **8a-8b**. The release tool **70** is run into the well after the production tubing is pulled. It is secured downhole to the packer at connection **72**, which can be a variety of configurations. A ball seat **74** is retained by shear pins **76** and accepts a ball **78** dropped from the surface. Built up pressure pushes down of piston **80** and piston **82** through port **84**. Piston **80** bears down on piston **82**. Piston **82** bears on shoulder **86** on the packer or anchor P. Thus the packer or anchor P is subjected to a longitudinal extension from an uphole force at connection **72** and a downhole force at shoulder **86**. The resulting radial retraction allows removal of the packer or anchor P with the tubing **72**.

[0053] Figs. **9a-9b** show a thru-tubing variation of the release technique. The release tool 88 can be run in on slick line or wire line to latch into latch **90**. Pressure is developed on pistons **92**, **94**, and **96**. Ports **98** and **100** allow access to pistons **94** and **96** respectively. Piston **92** bears on piston **94**, which in turn bears on piston **96**. Piston **96** rests on shoulder **102** on the anchor or packer P while the other end of the release tool **88** is latched at latch **90**. Ports **104** and **106** allow pistons **92** and **94**, respectively to move by

allowing fluid to pass. Accordingly, applied pressure in tubing **108** or generated pressure from an electric line setting tool such as an E-4 made by Baker Oil Tools, stretches the packer or anchor **P** to get the slips **18** and **22** (see Fig. **1**) to let go of their grip of the tubular or casing **C** in the manner previously described.

[0054] Figures **10a-10d** and **11a-11d** show a packer of known construction except that it has a narrow portion **110** in its mandrel **112**. It has a sealing element **114** and slips **116** extendable with cones **118** and **120**. A lock ring 122 holds the set. In the past, the packer could be released by releasing the lock ring by cutting the mandrel of the set packer downhole, as illustrated in U.S. Patent 5,720,343. However this technique had its uncertainties due to doubts about placement of the cutter and knowledge as to if the cut was completed. The release technique for such packers of the present invention, removes such uncertainties. The release tool **122** can be run thru tubing on slick line or wire line and latched at latch **124**. A pressure intensifier **126** of the type previously described rests on shoulder **128** of the packer or anchor **P**. Application of pressure from the surface or the electric line tool puts opposing forces at latch **124** and shoulder **128** until the narrow portion **110** fails in tension. This releases the hold of the set position by the lock ring **122** and allows extension and radial retraction of the slips **116** and the sealing element **114**. The break **130** is shown in Fig. **11d**. If there are multiple packers or anchors **P** in the well, the process can be repeated for each one that needs release. As well, the setting process can be repeated to set in any order desired, other packers or anchors **P** to isolate a desired zone for example. The release tool can be delivered through the production tubing or on wire line or slick line after the production tubing has been removed. After release, the release tool can drop the tool just released or it can stay with it and allow the released tool to be removed to the surface.

[0055] Other downhole tools can be expanded and extended for release in the manner described above other than packers or anchors. Some examples are screens and perforated liners.

[0056] The techniques described above will also allow for expansion and extension of a variety of tools more than a single time, should that become necessary in

the life of the well. Extension of the downhole tool for release does not necessarily have to occur to the extent that failure is induced, as described in conjunction with Figs. **10** and **11**. The extension of a tool such as the packer or anchor **P** an embodiment of which is shown in Fig. **1**, can allow it to be re-expanded with the variety of tools described above.

[0057] Tubing itself can also be expanded and extended for release using the techniques described above.

[0058] Although the retrieving tool has been illustrated as abutting a shoulder to obtain the extension, the shoulder can be provided in a variety of configurations or can be replaced with a gripping mechanism such as slips on the release tool. The slips could alternatively replace the latching notch while still putting a downhole force on the lower shoulder. The mandrel can also have an undercut and collets can engage the undercut to put the requisite extension force on the mandrel body.

[0059] Selected zones can be isolated or opened for flow with the techniques previously described. Pressure intensifiers of various designs and pressure magnifications can be used or, alternatively, no pressure magnification device can be used.

[0060] If the through-tubing tool is used with the explosive charge as the pressure source, then it will need to be removed and the charge replenished before it is used to expand another device in the well. The hydraulically operated through-tubing tool can simply be repositioned and re-pressurized to expand another downhole packer, tubular or other tool.

[0061] The various forms of the release tools can be used with conventional packers that set with longitudinal compression of a sealing element and slips with the set held by a lock ring by extending that packer to the point of mandrel or other failure, which can release the set held by the lock ring.

[0062] Referring now to Figure 14, a preferred embodiment of the packer **P** is illustrated. The mandrel **150** has an undulating surface **152** defining peaks **154** and adjacent valleys **156**. The peaks **154** and valleys **156** can be rounded, blunt or may define a sharp angle, although a slight radius is preferred. Slips **158** and **159** straddle the sealing

element 162. Slips 158 and 159 each have an undulating surface 160, which matches undulating surface 152. The number and height of the undulations can be varied to meet the expected performance conditions for the packer P. Because of the slant orientation of the undulations 152 and 160 a net force from uphole acting in a downhole direction (or vice versa), represented by arrow 161 in Figure 15, will create a radial component force acting on the slips 158 and 159 whose size depends on the size of the net force acting uphole or downhole and the angle of the mating surfaces of undulations 152 and 160. The resultant force is shown by arrow 163 and it has a radial component shown by arrow 165 and a longitudinal component shown by arrow 167.

[0063] The sealing element 162 has nodes such as 164 and 166 under it. These nodes are protrusions from the mandrel 150. They act to increase the internal pressure in the sealing element 162 so that it retains sealing contact despite load direction or load size changes. Augmenting the increase in internal seal pressure that is caused by one or more nodes such as 164 and 166 are anti-extrusion rings 168 and 170 that are mounted above and below the sealing element 162. As seen in section in Figure 15, the rings 168 and 170 have sloping surfaces 172 and 174 respectively to engage slips 158 and 159, respectively to help push out close wickers 176 and 178. The close wickers 176 and 178 are closer to rings 168 and 170 to insure that the rings 168 and 170 are firmly positioned to prevent extrusion of element 162 despite changing loads amounts or load direction. At the same time, the internal pressure in the sealing element 162 working against rings 168 and 170 pushes their respective sloping surfaces 172 and 174 under slips 158 and 159 so as to enhance the bite of not only the close wickers 176 and 178 but also the remaining wickers 180 and 182.

[0064] Figure 16 illustrates the use of a tube or line 184 to carry signal lines or fluid pressure to locations beyond the packer P. Line 184 runs outside the mandrel 150 and through the sealing element 162 and between sets of slips such as 158 or 159. Line 184 can alternatively run through a portion of the body of mandrel 150. Fiber optic or electric lines can be run in line 184 to control downhole equipment or gather data from below the packer P.

[0065] Figures 17 and 18 show the limitation of prior art systems in the ability to radially load the slips. Sloping surfaces **186** and **188** on cones **190** and **192** have limited contact with slips **198** and **200**. As seen in Figure 18 that contact is limited between points **194** and **196** of surface **188**, for example. The spacing between the points **194** and **196** can't be increased because the taper angle must stay in a preferred range to transmit sufficient radial force to a slip such as **192** and making the spread between points **194** and **196** longer can effectively be done at the expense of decreasing the internal bore of the packer for a given exterior run in dimension. Accordingly, the prior art packers set by relative longitudinal movement, whether initiated by mechanical force or hydraulic pressure were limited in the length of the slips **198** and **200** to which radial loading could be applied. This limitation forced higher stresses to be applied to the tubular against which the slips **198** and **200** were actuated. The packer **P** of the present invention solves this problem using the expansion technique. As shown in Figure 19, mandrel **150** expands below a slip such as **158** by applying a radial force between points **202** and **204**, with point **204** being on surface **172** of ring **168**. This spacing between points **202and 204** can be as long as desired and much longer than the design parameters of the prior art designs illustrated in Figures 17 and 18 would allow. As a result, the desired contact force is applied over a substantially grater contact area, extending to a substantial portion of the length of longer slips, to greatly reduce the stress applied to the surrounding tubular or the formation if in open hole. As previously stated, in a cased hole, for example, the surrounding tubular need not be deformed as the wickers such as **176-182** dig in for a bite. The present invention allows for the use of more wickers to decrease the stress on the tubular from the penetration. Even if all the wickers bottom into the surrounding tubular, the resulting stress is reduced, when compared to the prior art, because the contact area over which radial force is transmitted has been dramatically increased. The radial load can be applied to over 90% of the length of the slips that can be used in any desired length.

[0066] Figures 20-23 show an application of the packer **P** to drilling out a well plug **206** with a bit **208**, with the packer **P** mounted right above on the drill string **210**. After the plug is drilled out the annulus **212** can be isolated when the packer **P** is expanded. In Figure 21, the plug **206** is fully milled out. In figure 22, the bit **208** is

released. In figure 23, the packer **P** is expanded into contact with the wellbore **W**, isolating the annulus **212** around the drill string **210**. Production can start through string **210** with the annulus **212** sealed off by packer **P**. The advantage is the robustness of the packer to allow cuttings to be circulated around it. The prior art technique dispensed with annulus isolation and allowed communication into annulus **212** as the well was produced into string **210**. In gas wells, potentially corrosive gasses could migrate into the annulus damaging the wellbore **W**, which could be casing of a material incompatible with the migrating gas. Even circulating or reverse circulating mud of a predetermined weight into the annulus, in the past, without annulus isolation, did not insure that undesirable fluids would not migrate into the annular space. The packer **P** of the present invention can be used to provide positive annulus isolation in such applications, as illustrated in Figures 20-23.

[0067] Figure 24 illustrates a liner **214** suspended from a liner hanger **216** with the packer **P** serving as the liner top packer in wellbore **W**, which can be cased or uncased.

[0068] Figures 25-28 illustrate the use of the packer **P** initially as an isolation packer and subsequently as a production packer. As shown in Figure 25, the packer **P** is expanded into a sealing position. The packer **P** is shown schematically. It may have a removable plug **218** that sits below its body. Plug **218** can be run in with the packer **P** and portions of the packer above the plug **218** can be expanded into sealing position with the wellbore **W**. As shown in Figure 26, an assembly comprising of tubing **220**, seal assembly **222**, retrieving device **224**, and a sinker bar **226** are lowered into position adjacent the plug **218**. In Figure 27, the plug **218** has been knocked out and the seal assembly **222** is in seal bore **223** of the packer **P**. Figure 28 illustrates the release tool and retrieving device **224**, as previously described, stretching the packer **P** to get it to release and retaining a grip on it after release so it can be removed.

[0069] Figures 29-32 illustrate a one trip hydraulically set packer **P** that is run in and set using a pressure intensifier **228**. Mounted inside body **230** is a piston **232**. A port **234** communicated into annular space **236** defined by lower sub **238**. Seals **240-248**

isolate annular space **236** so that applied pressure after ball **250** lands on seat **252** puts a downward force on piston **232,** which moves in tandem with sleeve **254**. Seal **256** allows pressure to be built up on landed ball **250** until a predetermined value, at which point the shear pin or pins **258** break to release ball **250,** as shown in Figure 31b. As shown in Figure 29a, annular space **260** is defined between piston **232** and mandrel **262**. Seals **264-268** and **240-244** isolate the annular space **260.** Piston **232** has a shoulder **266,** which decreases the volume of annular space **260** as the piston **232** is moved downwardly. The pressure is intensified because the radius of seal **248** is larger than the radius of seals **242-244** and **264-266.** The downward force on ring **254** is converted to a greater force applied to a smaller radius, where shoulder **266** is located. As a result, the mandrel **262**expands radially to push out the sealing element **270** and the slips **272-274** in the manner previously described. After the packer **P** is set, a further buildup of pressure on ball **250** breaks shear pin **258** to release ball **250** downhole. Figure 32 shows an alternative way to set the packer **P** using a slick line plug, not shown, that lands in groove **276** and seals adjacently using seals carried on the plug. The packer **P** is then set using the pressure intensification as described with respect to Figures 29-31. At the conclusion of the setting process, the plug is captured with a fishing tool on a fishing neck, in a known manner and hoisted out. No matter how the packer is set, the intensifier **228** is built into it and stays in position after the packer **P** is set to become a part of the central passage through the packer **P**. The packer **P** is run in on one trip and pressured up after the object such as ball **250** or a slick line plug (not shown) is quickly placed in position to allow pressure buildup to initiate expansion. If using the slickline plug, multiple packers can be run on a single string and set in a predetermined order or in any random order.

[0070] Referring to Figures 33a-33e, an alternative embodiment is disclosed. The slips **300** and **302** now each have at least one inwardly oriented depression **304** and **306** respectively. The expansion mandrel **308** is preferably cylindrical in the region of slips **300** and **302** but may have slight indentations **310** and **312** to orient the slips **300** and **302** in the run in position. As shown in Figure 33a, a seat **314** accepts a ball **316** for movement of the piston 318. Piston **318** moves between outer seals **320** and **322** and inner seals **324** and **326** to reduce the volume of cavity 328. Because the area of cavity **328** is smaller than the piston area at seat **314** with ball **316** landed on it, there is a

magnification of applied pressure on the ball **316** that acts to expand the expansion mandrel **308**. Figures 34d-34e show what happens as the expansion mandrel **308** expands. It not only pushes the slips **300** and **302** outwardly to make supporting contact with the wellbore or tubular **330** but it also assumes the interior shape of the slips **300** and **302** by expanding into their respective depressions **304** and **306**. Those skilled in the art will appreciate that the depressions **304** and **306** may be on the mandrel **308** and that slips **300** and **302** can be cylindrical or have outward projections on their inwardly oriented surfaces. The advantage to the embodiment in the Figures 33-35 is that it is simpler to put recesses **304** and **306** into the slips than to prepare an expansion mandrel and matching slips with mating undulating surfaces. Since there is some shrinkage in length during the expansion process, getting the undulations to stay meshed throughout the expansion process can become an issue. Using the preferred embodiment of a depression on the slips not only better secures the slips **300** and **302** to the expansion mandrel **308** but it takes better advantage of the shrinkage during expansion to hold the slips **300** and **302** in position. The number, shape and depth of depressions **304** and **306**, as well as their location on the slips or the expansion mandrel can be varied depending on the application. Figure 35f shows the seat **314** and the ball **316** being blown out of the way after the set position is obtained. A plug or some other object can be used instead of ball **316** to temporarily obstruct the interior passage to allow pressure buildup to set the Packer **P**.

[0071] Apart from reducing stress on a surrounding tubular or wellbore, the packer **P** of the present invention also conforms to oval shaped casing as well as provides increased collapse resistance in the set position. The packer **P** can be delivered into casing on wireline or slickline or on wireline or slickline through tubing. Alternatively coiled tubing can deliver the packer **P** into casing or through tubing. The packer **P** can be set hydraulically in one trip as described or in two trips when combined with an intensifier that needs to be removed after expansion. The retrieving tool for the packer **P** can be delivered into the packer **P** in the variety of ways the packer **P** can be delivered. The release tool preferably stretch the packer **P** sufficiently until it releases and can be combined with a pressure intensifier. The releasing can be done with one trip or additional trips. The packer **P** can be used in a variety of applications apart from those

described in detail above. Some examples are frac/injection, production, feed through, dual bore, zone isolation, anchored seal bore, floating seal bore, Edge set, combined with sliding sleeve valves, and setting in a multilateral junction.

[0072] The simplicity of the packer **P** lends itself to rapid development with less testing than other prior art designs because its behavior under expansion forces is more predictable. Prior art packers were compressed axially to expand radially and had many parts that moved relatively to one another. It was difficult to predict how the seal would react to an axial compressive force. As a result complex programs were developed to predict seal behavior under compressive force. With the packer **P** on the other hand, the reaction of the seal to expansion is more readily predicted. Additionally, prior designs required a variety of anti-extrusion systems and those needed testing to see that they would deploy before extrusion had actually taken place. With the packer **P** scaling up from one size to another is also simplified.

[0073] The packers **P** can be introduced quickly at different levels in the wellbore and set or released selectively with ease. In another application the packer **P** can be run in on tubing and then pumping cement through the tubing and out around the packer, followed by setting the packer. The packer **P** can be used as a velocity string hanger below a safety valve. The packer **P** can have multiple bores and it can be set in not only out of round casing but also in the reformed leg of a multilateral junction. The packer **P** either assumes the oval shape or conforms the oval tubing back to a round shape. The expansion technique enhances not only collapse resistance but also corrosion resistance. The reason is that by using a swage to expand, higher stresses are imposed than if pressure is used, with the result being a loss in corrosion resistance and collapse resistance. As an alternate to release by stretching, release can be accomplished by isolation of the expanded segment and pulling a vacuum to collapse the mandrel sufficiently so that it will release for removal.

[0074] The rings **168** and **170** keep the wickers **176-182** engaged despite reversals in load direction. Internal pressure in the sealing element **162** creates a radial force on the slips **158** and **159** through the ramped surfaces on rings **168** and **170**. The

nodes **164-166** allow the use of a non-elastomeric seal. Pressure one end of seal element **162** transfers load to another node on the lower pressure end of the seal element **162**. The presence of multiple nodes increases the internal pressure to help maintain the seal as loading conditions shift.

[0075] Another distinction from the prior art packers is the use of even loaded collet type slips that are urged into greater contact with the casing when uphole or downhole pressures increase. Due to the undulating contact between the slips and the mandrel, such axial loading from pressure is not transmitted to the sealing element; rather it just causes the slips to grab harder.

[0076] The above description is illustrative of the preferred embodiment and many modifications may be made by those skilled in the art without departing from the invention whose scope is to be determined from the literal and equivalent scope of the claims below.